EXAMINATION OF ORGANIC REMAINS IN POSTGLACIAL DEPOSITS.

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LITTLE or no attention has been paid in America to the study of fossil plants in the postglacial deposits. They do not offer such a fascinating field to the investigator as the tertiary and other older formations. They do not show a multitude of forms of animal and vegetable life, beautifully preserved from the times when the earth was young; only a few fragments of recent types, difficult to determine and mostly of a very diminutive size, necessitating a constant use of the microscope. But they are, nevertheless, interesting, especially to the student of descriptive phytogeography, as recorders of the history of the vegetation, and to some extent as indicators of climatic conditions in times gone by. In this respect the great importance of an investigation of, for instance, the formation of peat-bogs, cannot be overrated, and in northern Europe this study has developed during the last decades into a special science, called in Germany *Moorkunde*. A name of a more international character, telmatology,[1] has been used by some authors,[2] and seems acceptable.

The Scandinavian countries, especially Sweden, have been the center of this study, and consequently, the development of the Scandinavian Flora and vegetation is better known at the present day than that of any other part of the world.

It is the purpose of this paper to give a brief review of the methods for collecting, preserving and examining the plant-remains in recent deposits, as these methods are now generally employed by paleobotanists, with a few additions from the writer's experience in the study of telmatology. In another

[1] From **Τέλμα** = swamp or bog.

[2] Klinge, J., for example, nearly twenty years ago. Not having access to the literature, I cannot at the time of writing, ascertain who proposed this name. G. Lagerheim suggested (1902) a name derived from **Ηαύσιμος** *i. e.* = combustible, but both priority and suitability speak in favor of Telmatology.

place the development of these formations and their relation to certain plant-communities will be treated.

Japetus Steenstrup of Copenhagen was the first to begin the difficult task of identifying the organic remains in peat bogs and similar deposits. After him Axel Blytt of Christiania, A. G. Nathorst and Gunnar Andersson of Stockholm, Rutger Sernander and Henrik Munthe of Upsala have been the principal workers in this field. Many pupils of Andersson and Sernander have in later years pursued the study in Germany, Russia and other countries, and the literature on the subject is rapidly increasing.

The first paper on the method of examining fossil plants in postglacial deposits was published by Andersson in 1892.[1] Improvements on his method were made known in 1892, 1893 and 1896.[2] Munthe gave (1894) a detailed account of biological investigation of clays,[3] and Professor G. Lagerheim[4] recently ('02) related some new experiences with regard to the technique of telmatological research.

All these papers are in the Swedish language and the writer thinks he is justified in bringing the methods in question under the notice of American paleobotanists and phytogeographers, as a study of the evolution of the plant-covering based on paleontological testimony is likely to find adherents in the United States and Canada, where postglacial deposits, so widely distributed and covering immense areas, offer special advantages for this line of research.

The principal kinds of recent deposits in which we meet with fossil plants, are fresh water alluvium, lacustrine deposits and peat bogs. Wherever these formations are developed, accumulation of partially decomposed organic matter has been the most important agent in their construction.

When this process of decomposition is proceeding in presence

[1] Om metoden för växtpaleontologiska undersökningar af torfmossar. *Geolog. fören. förh.* Stockholm, vol. XIV, pt. 2, pp. 165–175.

[2] Om slamning af torf, *loc. cit.* vol. XIV, pt. 6, pp. 506–508; Om metoden for botanisk undersökning af olika torfslag. *Svenska mosskulturförening. tidsk.*, 1893, and Om konservering af kvartära växtlämningar. *Geolog.fören.förh.*, vol. XVIII, pt. 6, pp. 492–498.

[3] Om biologisk undersökning af leror. *Geol.fören. förh.*, XVI, pt. 1, pp. 17–28.

[4] Torftekniska notiser, *loc. cit.*, XXIV, pt. 6, pp. 407–411.

of an excess of water, humic acid and certain hydro-carbons are formed, and it is to these substances the said deposits owe their anti-septic properties, which make it possible for organic remains to resist decay for a sufficiently long time to allow deposition of the sediment, in which they are finally imbedded.

Trees falling into the water, branches, roots, leaves, seeds, and other parts of plants are often in this way preserved, and retain sometimes their shape, color and anatomical structure to a surprising degree, so that there is no difficulty in discriminating the distinct species. It is, however, only lignified and corky tissues that are able to resist decomposing. All those organs which have not cell-walls modified in this way, are liable to be destroyed. Of leaves, for instance, only the epidermis and vascular bundles remain, while mesophyll and similar tissues decay.

The fossil remains are therefore often quite different in appearance from the plants that fell into the water, where they were deposited. Among Salices that are found in post-glacial deposits, species with hard leaves, as *Salix aurita* L., *S. cinerea* L. and *S. nigricans* Sm. remain unaltered, both with regard to form and consistency, although, of course, the color is changed; the nervation is very distinct. In the case of *S. myrsinites L.* only the skeleton of the ribs is left. *S. lanata* L. and *S. lapponum* L. are very difficult to recognize, because the characteristic tomentum has disappeared, and instead, the nervation, which in the living condition cannot be traced, is rendered very conspicuous.

In beginning the study of telmatology one of the greatest difficulties met with is the fact that there are, as yet, only a few study collections accessible, and no complete works of reference with excellent illustrations and descriptions such as are available in other branches of paleontology. The student has usually to prepare for himself the comparative material he wants.

By means of certain maceration processes the same effect can be accomplished in a few minutes in the laboratory that required a long time in nature. Thus it can be also ascertained to some degree of probability, whether a certain plant can be preserved in a fossil state in mud, peat, and clays, or if it will be completely decomposed when subjected to the influence of water and other agencies in the deposits.

For this purpose the plant is boiled in Schultze's maceration mixture, which consists, as every botanist knows, of potassium chlorate and nitric acid. Leaves, seeds and other parts of the plants, which are usually found fossil, soon acquire the same dark-brown color that is so characteristic for peat, and it is almost impossible to distinguish these preparations from the real fossils. Plants, however, which are almost instantly destroyed by this strong reagent, never occur in the said deposits. It can, therefore, be taken for granted, if the tissues are destroyed within a minute or two, that the result would have been the same in water, but if only bleached, or in a lesser degree macerated, it can be supposed that the organ would have resisted decomposition.

These macerated objects can then be mounted and preserved in the way usually adopted for microscopic preparations. Every student of fossils in postglacial deposits should in this way secure the material needed for comparison.

The collecting of fossils consists partly of field work and partly of operations in the laboratory. For the former purpose the student should be supplied with the following tools. A small steel spade, about 20 cm. in length and 14 cm. in width, with a handle like that on a mason's trowel, and with sharp edges, for cutting purposes ; a pointed knife with a blade of at least 14 cm. in length ; a pair of forceps, a soft camel's-hair brush ; a white china plate ; and a pocket microscope. Further, a number of flat-bottomed test-tubes of different sizes : 60 x 18 mm., 50 x 16 mm., and 40 x 12 mm being the most suitable sizes ; strong, wide-mouthed glass bottles, 80 x 40 mm., and some glass jars of about 12 cc. capacity.

If collecting is done in deposits more or less petrified and hard, such as calcareous sinter or tuff, the usual tools of a geologist are needed.

Sometimes it will be found impossible to remove fossils found in loose sand deposits, because they are too brittle, and in such cases it is advisable to fix the sand particles together with water glass, as silicate of potassium or sodium, readily and completely soluble in water generally are called. Although the fossils preserved in this way lose their color, and if not prepared most

carefully will break, this method, nevertheless, has many advantages; and Andersson[1] recommends always to be supplied with a bottle of soluble glass when collecting in sand- and clay-deposits. If care be taken to let the preparations dry slowly, the result will often be surprisingly good.

At the places chosen for taking the samples of peat or similar soft deposits, vertical holes are dug to the desired depth, the cutting being trimmed with the sharp spade, care being taken not to disturb the succession of strata, or to get any recent plant fragments mixed into the mass. Careful notes of the freshly cut layers should be taken immediately, before the peat begins to darken through the influence of the air. Samples, 10 cc. in volume, should, in general, be taken at intervals of 50 cm. throughout the profile. Wherever any marked differences in the soil are observed, separate samples should be secured. The depth of every sample must be measured and noted on the labels and in the field book, as well as any observations regarding the consistency, color, odor, and other characteristics of the respective strata from which samples are taken. These samples are preserved either in jars or in clean canvas bags, and later examined in the laboratory.

The collector should also search for fossils on the spot. For this purpose the white plate is filled with water to the rim, and slices cut out from the stratum to be examined are carefully broken into pieces and washed, and any seeds or other remains removed with the brush and forceps, and preserved. This examination is facilitated if the peat is placed for some time in a diluted potassium or sodium lye, which must, however, be carefully washed away afterwards. Lagerheim's oxalic acid method, which will be described later, is still better for the purpose.

Series of samples are taken on different places of the bog, usually in a line across the deepest part of the formation so as to give a section of the basin, in which it has developed. The number of profiles to be opened depends naturally on the extent and topography of the formation, but from three to five profiles

[1] Andersson, G. Om senglaciala och postglaciala aflagringar i mellersta Norrland. *Geol. fören. förh.*, vol. xvi, pt. 6, p. 550.

between the centrum and the shore are sufficient in most cases for a bog of, say, 10 acres.

The collecting often has to be done under great difficulties on account of the swampy character of the peat, which is often of so loose a consistency, that it is impossible to open a hole to any depth. In this case an earth-auger or soil-sampler, has to be employed. Of these instruments there are many kinds in use. One of the best for peat sampling purposes, that has come under the observation of the writer, was described in 1894 by A. G. Kellgren.[1]

His peat-auger consists of a steel pipe 1.5 m. in length and about 4 cm. in diameter. The accompanying illustration (Fig. 1) shows how the auger is arranged. The lower end of the pipe is closed with a piston which is pointed at the apex, and can be lowered and raised in the pipe with a steel rod, managed from the upper end.

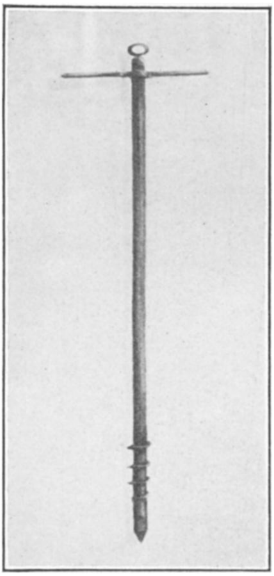

FIG. 1.— Peat-auger.

If the sample to be taken is from a compact peat, the auger is sunk to the required depth, the piston is drawn back into the pipe, and then the auger lowered for about 10 cm. The lower end of the pipe will thus be filled with the earth which the auger retains, when withdrawn. In order to secure the samples in a natural state, the first 10 cm. of pipe at the end of the auger is split in two halves, and these are secured by hinges on one side, and fixed to the main stem of the pipe with a screw arrangement which holds them together. When the sample has been obtained, this 10 cm. end of the pipe containing it is unscrewed and opened, thus allowing the sample to be removed intact.

[1] En ny konstruktion af mossborr. *Geol. fören. förh.*, vol. xvi, pt. 4, pp. 372–374.

When sampling is to be done in very loose or almost liquid sediments, the piston is pushed below the pipe, and when the end of this is filled with the mass, the piston is drawn back to its former position, which secures the sample.

The end of the pipe, which comes in contact with the sample should be kept scrupulously clean and free from rust. When the piston is withdrawn into the pipe, the cutting through the sediment, is, of course, done by the sides of the pipe as the auger is lowered. It is, therefore, essential that this part of the pipe be made of the best steel, so that the sides can be ground to a knife-edge and kept in that condition. The pitch of the screw must be low, and the boring should always be done very slowly. If samples are wanted from greater depths, the handle of the auger is shifted and new lengths of pipe and steel-rod are added.

The ulmic and humic substances, or those chemical compounds to which the peat owes its peculiar character, are developed in the presence of water and when dried are subject to molecular alterations, by reason of which they lose their ability to re-absorb water. There is no reagent known, as yet, that can restore to dry peat its original properties. The usual means employed in microscopy for causing swelling do not give satisfactory results. Experiments with lactic acid have also failed.

All collections from peat and other moist deposits have, therefore, to be kept in some preserving fluid, and must not be allowed to dry, because this would considerably increase the difficulties of determination, and in some cases even make identification impossible. With collections from fossiliferous clays and sand deposits this is not absolutely necessary, but desirable. Früh has shown through experiments that the ulmic and humic substances are immune for bacteria and fungi, and by reason of this they are almost completely absent from the peat-water, which can be used for some time as a preserving medium. Alcohol is generally employed, but samples of peat can be kept for years in a fresh state covered with the swamp-water in air-tight vessels, if previously disinfected with carbon disulphide In case the samples have to be transported for some distance, the vessels containing them should be well filled with the preserving liquid so as to prevent unnecessary shaking.

Dried peat can to a certain degree be made suitable for examination, if boiled in water for three hours and afterwards saturated with 5 *per cent.* ammonia water for 48 hours. It should then be subjected to the same treatment as fresh peat, when prepared for examination. Fossil seeds and fruits, which have been allowed to dry, can be restored to their original shape and volume by the influence of a weak (2–3 *per cent.*) ammonia solution.

When peat has been under the influence of air for some time, it darkens, and the more this change of color proceeds, the more difficult will it be to find and determine the fossil remains. If the water contains iron in solution, as is often the case, the samples will, in a very short time, be almost black, which considerably lessens the possibility of a successful botanical examination.

In order to restore the original color to the fossils it is therefore necessary to let them undergo a bleaching process. This is effected in several ways. The oldest method, employed by Schröter[1] (1883), was to use Schultze's mixture for bleaching, as neither ammonia, potassium hydroxide, or calcium hypochlorite gave good results. This reagent certainly makes the dark-brown and opaque plant-remains from the peat transparent, so that nervation, cells, etc., can be studied, but usually acts too strong and often destroys the objects.

At present, Gunnar Andersson's nitric acid treatment is the method most used. According to this method the peat samples are put for 24–30 hours into commercial nitric acid diluted with twice as much water. In the phytogeographical laboratory of the University of Upsala, where the writer first studied telmatology under the guidance of Dr. Sernander, a solution of one part nitric acid (65 per cent.) and 3 parts water was used for macerating peat of loose texture, and one third acid when the samples were compact. From 12 to 16 hours treatment according to my experience, is sufficient in most cases for bleaching the peat, so that the fossils can be washed out.

The advantages of this method are certainly very great: all

[1] *Die Flora der Eiszeit.* Zürich, 1883, page 21.

clays, whether calcareous or not, disintegrate, and the samples of the usually tough and oily mass from the strata lying under the peat proper swell and are macerated. The dark color is bleached, the fossils are filled with gas-bubbles and float on the surface of the fluid, so that they can easily be collected.

But the method also has its drawbacks. Nitric acid of the strength required is liable to act with more or less damaging results on the organic tissues, and thus make the fossils more friable still than they were before. Certain minute microscopical remains are usually totally destroyed.

The process of bleaching should, of course, be done under a hood or similar device to get rid of the fumes of the acid. In case the examinations are done in the field one is confronted with the additional difficulties of transporting the acid.

Lagerheims's method of bleaching with oxalic acid is undoubtedly an improvement, because no injurious fumes are developed, the fossils are not affected, and the acid is in a solid form, and consequently easy to handle and transport. From the fact that oxalic acid is able to decolorize organic iron compounds Lagerheim concluded that it would be a good reagent for bleaching peat, especially when it contained iron in solution and had darkened in the air. Acting on this suggestion he found that pieces of peat immersed in a 3 *per cent.* solution of oxalic acid, almost instantly lose their dark color, which changes to brown. For the bleaching process a glass vessel is most suitable, and if this is exposed to daylight, or still better, to sunlight, the brown color fades gradually, until, after a few hours, the peat mass is ready for washing.

The influence of light is explained by the fact, already observed by Downes and Blunt (1879), that solutions of oxalic acid evolve carbon dioxide when exposed to the action of light. Other catalyzing agents are, for instance, salts of iron, which usually are present in peat. To the writer's knowledge the composition of these iron compounds that cause the dark coloring of peat has not yet been ascertained. Lagerheim is inclined to think that we have to do with some organic iron compound.

Peroxide of hydrogen is formed[1] in the process of oxidation

[1] Richardson, A.: The action of light on oxalic acid. *Proceedings Chem. Soc. London*, 1894, (137), 88.

of the oxalic acid solution, which probably takes place according to following reaction:

$C_2O_4H_2 + O_2 = 2CO_2 + H_2O_2$ and it is perhaps this peroxide of hydrogen that, in combination with some other compounds,[1] effects the bleaching.

According to Richardson, the total amount of hydrogen peroxide formed in the solution increases with the concentration of the acid, while at the same time the proportion of peroxide to acid formed decomposed decreases simultaneously, and since the described action of the head occurs with greater rapidity if considerably diluted, only a very weak solution should be used.

If the fossils, especially leaves, are wanted almost colorless, the following method of bleaching is recommended. A solution (not too strong) of potassium permanganate, is employed where they are allowed to lie for some time, and then transferred directly into the oxalic acid solution.

To extricate fossils from calcareous peat it is necessary to remove the carbonate of lime, and this is best done with hydrochloric acid. If, however, the material contains lime in a small degree only, application of the acid will result in effervescence, which causes the decomposition and penetration to take place very slowly and unevenly. In order to prevent this, the peat-particles are thoroughly saturated with strong alcohol, and the hydrochloric acid is applied afterwards. The separation will now proceed easily and uniformly, and the gas-bubbles are bursting so soon, that no undesirable foaming is caused. Should this occur, the mass is again treated with alcohol. The separated peat-material can then be preserved in the alcoholic calcium-chloride liquid.

Whatever method is employed for bleaching, this process has to be done very carefully, so as to prevent the fossils from being destroyed by the acids. The next step is the "slumming," or washing of the macerated mass. For this purpose there are different devices for slumming vessels. These are all constructed on the plan of creating a rising current of water through the mass, which is poured over a sieve of brass netting with meshes not smaller than 1.5 mm. in diameter.

[1] Hydrogen peroxide alone does not bleach peat.

A good arrangement is to have a porcelain vessel fitted with two sieves, the upper one with meshes of about 2 mm. and the lower 1.5 mm. The sieves are placed about 5 cm. apart, and two currents of water, the velocity of which can be regulated by cocks, should be used, one under each net. Figure 2 shows a contrivance made on these principles and used by the writer with good success. The residue of the slumming need not be examined, if portions of the sample have been reserved for microscopic examinations for spores, pollen, algæ, bryozoa, molluscs, rhizopods, cirripeds and other Crustacea, fragments of echinoderms and insects, and other minute animal remains. In order to get a more complete collection of these fossils the slumming water, which, of course, has previously been examined and found free from diatoms, should be allowed to pass through a silk net as shown in Fig. 2.

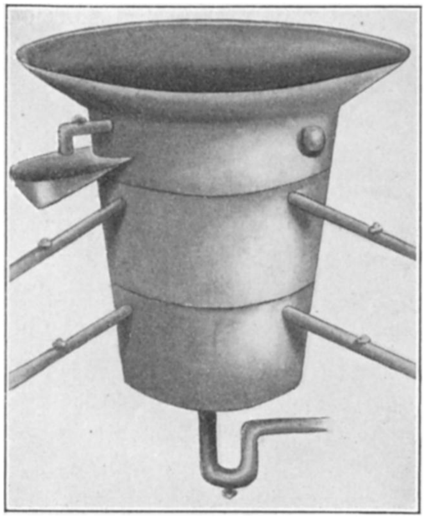

Fig. 2.—Slumming vessel.

The slumming is comparatively easy if the material is somewhat sandy, but when sticky or miry, the mass has to be stirred and sometimes broken by the hands of the operator.

With regard to the slumming and preparation of clays for the study of diatoms or for mechanical analysis, the technical details have so often been described that we need not go into them here.

When the fossils are ready for preservation twigs, pieces of bark and wood, cones, nuts, rhizomes of grasses, and other larger fossils are usually kept in 40 *per cent.* alcohol or in a 1–2 *per cent.* solution of formalin. Seeds and fruits are preserved in

alcohol or in sterilized water. In the latter case, the glass tubes are immediately sealed with melted paraffin, which acts both as a cork and as an isolating medium. Larger leaves are best preserved in a mixture of 2 parts of glycerine, 1 part carbolic acid, and 7 parts water. Remains of delicate mosses and small leaves, parasitic fungi, and algæ should be preserved in Canada balsam like ordinary microscopic preparations.

Andersson recommends another plan of preserving, which has its advantages. After being dehydrated in alcohol, the fossils are transferred to a 30 *per cent.* solution of benzin-alcohol, thence to a 70 *per cent.* solution, afterwards, to pure benzin, and subsequently to a saturated solution of naphthalin in benzin. The fossils are kept here for some time, until the fluid has well penetrated. When the objects are drying the benzin evaporates, and the surface is covered with small crystals of naphthalin. These gradually evaporate and the object will remain almost entirely unaltered. No shriveling is observed, and the contraction is estimated to be only 1 *per cent.* This treatment can be employed well for preserving larger objects.

When examining and mounting minute and fragile fossils, it will be found convenient to do the bleaching on the object-slide. The material is then washed in water in order to remove all the acid, and afterwards placed in alcohol until all gas-bubbles have disappeared. The washing should be repeated in absolute alcohol, and when the objects are thoroughly dehydrated they are transferred to a mixture of equal parts of xylol (or toluol) and absolute alcohol, subsequently to pure alcohol for a moment, and by this time they are ready for mounting in Canada balsam.

The fossils are usually rather brittle, so that when sections are wanted the razor and freehand cutting will be found unsatisfactory and imbedding in paraffin and the microtome have to be employed as for histological work.

For an exhaustive investigation, the statistical method will be useful to follow, and from the proposed size of samples 10 cc., a fair idea can be obtained of the quantity of fossils in a certain stratum.

To get a clear conception of the history of the vegetation of a place, it is not, however, sufficient to examine the fossils in the

deposits. The topography of the neighborhood has to be carefully studied, and the existing vegetation investigated, especially with regard to composition and relation of the various plant-communities. But also ecological conditions have to be observed in this connection, because in some cases they are of considerable help in interpreting the successive evolutional phases of the vegetation.

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